

Temperature Sensitivity of a Piezo-Electric Sensor used for Wind Erosion Measurements

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Introduction

The use of piezo-electric elements for the determination of moving particles is well documented in wind erosion literature (Arens 1996, Fryrear *et al.* 1991, Gillette *et al.* 1996, Gillette and Stockton 1986, Larney *et al.* 1995, Stout 1997). As part of another study (Heidenreich *et al.*, 1999) we have calibrated an instrument, based on a piezo-electric quartz crystal (SENSIT™) with data derived from instrumentation with a different underlying measuring principle (passive dust catcher) (Fryrear 1986). SENSIT™ measurements are expressed as particle flux (impacts per square meter per second) and kinetic energy count flux (erg per square meter per second). The kinetic energy output displays a particle impact independent background noise. To minimize measurement errors of the kinetic energy, we first need to subtract the background kinetic energy.

Methods

Method 1: Average constant

Assuming a constant background noise level a numeric method was chosen to determine the value. The constant was calculated by averaging the kinetic energy (KE) per logging interval [LI] for particle count $n(t) = 0$ for each sampling period $t=0$ to $t=T$.

Equation 1:
$$\overline{KE}_{\text{Background}} = \frac{\sum_{t=0}^{t=T} KE_{(t)n(t)=0}}{\sum_{t=0}^{t=T} LI_{n(t)=0}}$$

We dismissed this assumption of a constant background noise because of the large standard deviation about the mean.

Method 2: Temperature dependent background noise determination

One physical feature of piezo-electric cells is their sensitivity towards changes in temperature. The cells are a lead zirconate titanate composition $[Pb(Zr,Ti)O_3]$ which have a pyroelectric sensitivity of $k_q = 4.2 \cdot 10^{-4} \text{ K}^{-1} \text{ m}^{-1}$. We analyzed approximately 10,000 logging intervals each one minute long and without impacting particles. The correlation coefficient $\rho = 0.118$ of the kinetic energy as a function of temperature change in 10 minutes indicated that the velocity of the temperature changes (dT/dt) is too slow to have a significant impact on the signal (Figure 1). We found a strong correlation between kinetic energy background noise and ambient air temperature (Figure 2). The correlation factor between ambient temperature and kinetic

background energy was $\rho = 0.85$. Other factors suspected to have an influence on the background kinetic energy, such as wind speed and barometric pressure, had no correlation.

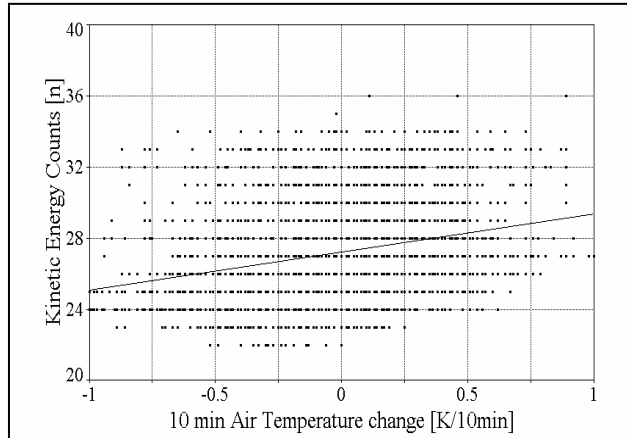


Figure 1:

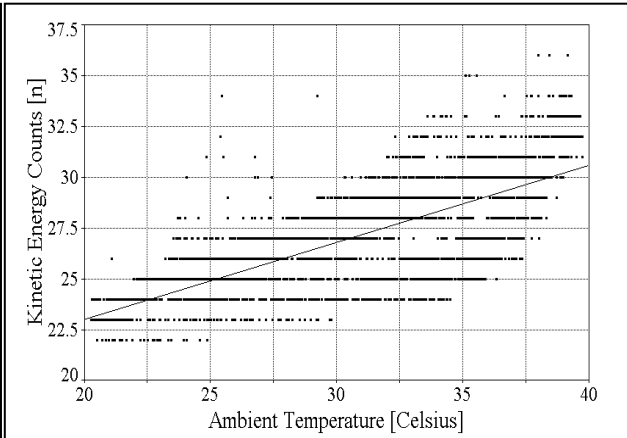


Figure 2:

A visual inspection of the time series data indicates a time lag between the temperature and the reaction of the kinetic energy signal. This can be explained with the experimental set up of the SENSITTM. The instrument was buried underground with the sensing ring 4-5 cm above ground. The insulating effects of the soil would explain the time difference between changes in ambient air temperature and instrument temperature. To find the appropriate time lag to apply to the correction factor we repeated the correlation analysis whilst shifting the Kinetic Energy data in 20 minute intervals from 0 to 240 minutes (4 hours).

We found the optimum correlation factor $r = 0.89$ at $T = 112$ min (Figure 3).

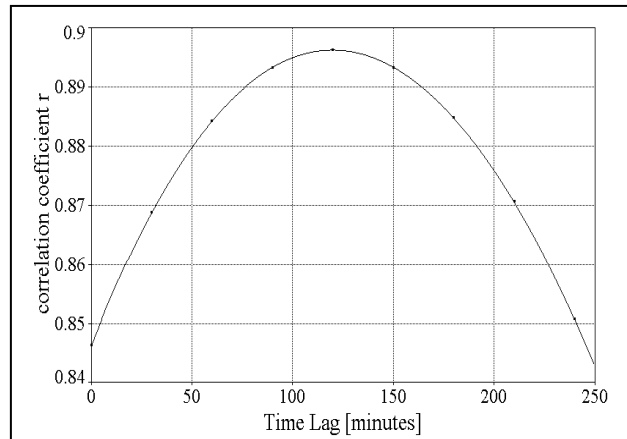


Figure 3: Temperature Time lag [minutes] against correlation factor r

In order to keep the required adjustment of the background kinetic energy level simple, we chose a linear fit of the form $y = a + bx$. The result for the examined instrument is

$$KE_{Background(t)} = 10.2 + 0.493 * T_{(t-112 \text{ min})}$$

Discussion

The examined piezo electric instrument clearly has a dependency of its kinetic energy output channel on the ambient air temperature, which in turn influences the soil / instrument

temperature. The maximum correlation between kinetic energy and temperature for determining the background kinetic energy signal was found at a time lag of $t=112$ min.

Possible causes of this temperature interaction could be either the ceramic cell itself or the signal conditioning electronics (i.e. a temperature sensitive amplifier transistor). The data logging system is unlikely to be the cause of the temperature dependency because the signal transfer is digital and therefore rather secure in its accuracy. Further experiments are required to determine which of the above mentioned possibilities causes the oscillation. This could, for example, be done by cooling the instruments body, and thereby the electronic components, to a constant temperature and then changing the ceramic cells temperature.

Conclusions

Care should be taken when utilizing the kinetic energy channel of the SENSITTM to calculate particle mass flux because the accuracy when determining the background noise level will govern the accuracy of the calculated flux. This applies mainly to small events where the noise to signal ratio will remain large compared to times of high saltation activity. Field experiments undertaken with the described instrument are often event based and therefore do not necessarily include two hours before the event. This should be taken into account when setting up recording parameters / intervals in future experiments.

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